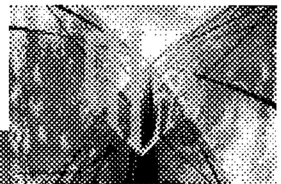
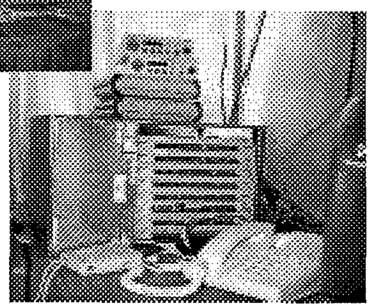
Testing Runtime Infrastructure/ Network Interactions for Latency





A Technical Paper from the Joint Advanced Distributed Simulation Joint Test Force

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ABSTRACT: The Joint Advanced Distributed Simulation (JADS) Joint Test Force (JTF) is chartered by Office of the Secretary of Defense to investigate the utility of Advanced Distributed Simulation (ADS) Technology to Test and Evaluation (T&E). JADS is executing three test programs (C4I, Precision Guided Munitions, and Electronic Warfare) representing slices of the overall T&E spectrum as well as observing other activity within the T&E community to form its conclusions. One of the slices, the Electronic Warfare test, is using HLA. To understand expected latency prior to the test execution, JADS is building a testbench to integrate and test the hardware and principle software components. This paper discusses the JADS plan to test the wide area network system latency prior to building the network and hosting the self-protection jammer (SPJ) test federation. The primary focus of this paper is on the process and tools used by JADS to characterize the RTI/network interactions, the system characterization measurements made in the testbed, and how that characterization will be fed back into the federation design.

1. Introduction:

HLA is a rapidly evolving product. As it continues to mature, there are a number of questions that users must address as they build their federations, particularly if the federation requires high performance from the communications infrastructure. Some of these questions are: "How do I determine what performance I need from the RTI for my federation?", "How do I communicate that to potential RTI suppliers?", and "How do I determine that the RTI I've received meets my requirements?" These questions will become more relevant in the future as the RTI evolves into a more commercial-like shrink-wrapped product.

The federation and the communications infrastructure are a complex system designed to meet the sponsor's objective. Complex systems require good system engineering process or a lot of luck to succeed. The Defense Systems Management College uses the diagram shown in Figure 1.0 to depict the systems engineering process. The requirements analysis and functional analysis/allocation parts of the system engineering process are covered in the first three steps of the Five-Step FEDEP process. Synthesis occurs in step 4 of the FEDEP process, federation integration and test, supported by associated VV&A and applicable test activities. All this suggests that federation development effort based upon performance driven requirements may be expected to bounce back and forth across the first four steps of the FEDEP as the federation design is iterated through the system engineering process. It should be obvious from this discussion that we feel RTI testing alone, while interesting and informative, needs to be part of an overall plan. RTI testing for high performance federations must be accomplished in concert with a full characterization of the other communications infrastructure components, the federates, and the Federation Object Model. Furthermore, if the results of the characterizations indicate performance shortfalls, those results need to be fed back into the sponsor needs and federation objectives as well as the federation design.

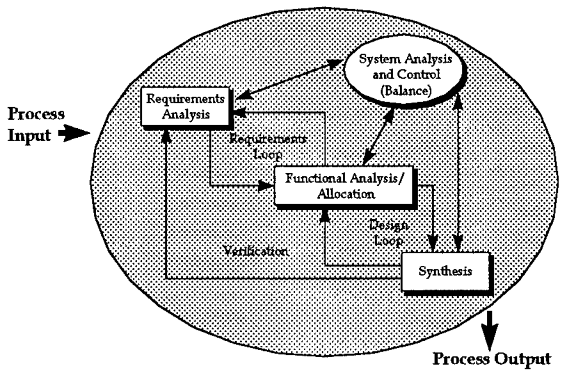

Figure 1.0 System Engineering Process

A sensible systems engineering approach also provides a basis for determining the performance a federation needs from the communications infrastructure and the RTI. The JADS derived requirements are presented as part of this paper to provide context for the test discussion, but the primary focus of this paper is RTI testing. The rest of this paper will focus on the suite of tests that will be used to determine that the Wide Area Network (WAN) equipment and RTI 1.3 meet the Joint Advanced Distributed Simulation (JADS) Electronic Warfare (EW) test federation requirements. This discussion begins by presenting a quick introduction of the JADS test program, the objectives of the EW test federation, and a brief description of the derived RTI requirements. With that background, the RTI test philosophy and objectives are discussed, followed by a discussion of the RTI test approach.

2. Background

JADS is an OSD sponsored Joint Test Force chartered to determine the utility of Advanced Distributed Simulation (ADS) technology for Test and Evaluation (T&E) of military systems. JADS is doing this by looking at three slices of the T&E spectrum. One of those slices is the JADS EW Self Protection Jammer test. This test will use two HLA compliant federations to recreate an actual Open Air Range (OAR) test of an EW system under test (an AN/ALQ-131 Block II self-protection jammer) to see how the test results using the HLA federations correlate with the OAR results.

The OAR test represents an effectiveness test of the airborne self protection jammer. One referent test condition will be repeated to gather a large sample of jammer effectiveness data. The environment, the threat systems, and the jammer are all instrumented to allow standard measures of performance to be calculated and to allow the engagements to be recreated in the federations. During the test phases using the HLA federations, each OAR pass will be recreated, the federate interactions will be monitored, and the measures of performance will be calculated in real-time.

2.1 JADS Performance Requirements

Closed loop testing using distributed simulation technology runs the risk that the communications infrastructure used to carryout the interactions between objects will change the outcome either through lost interactions, or by changing the temporal nature of the interaction. This temporal change is usually an increase in the time for the interaction to occur and is called latency. The amount of allowable latency depends on the nature of the interactions and the decision cycle of each system. The EW test interaction of interest is the threat radar activation, jammer identification and response, and associated threat response. Depending on how the engagement is carried out, the interaction can be the jammer's computer working against the threat computer or the jammer's computer working against the threat's human operator. Due to limitations in the threat radar federate, we will be looking at the latter interaction exclusively. Therefore, the limitations that we have placed on the communication infrastructure latency is 500 milliseconds. That means that from the time that the radar changes state, the infrastructure has 250 milliseconds to get that message to the jammer and another 250 milliseconds to return the jammer's response. The jammer's decision cycle time is excluded from the 500 millisecond latency. We refer to this as an "end-to-end interaction" during the EW test event. Of the 250 milliseconds, the RTI is allocated 150 milliseconds. It is important to note that this requirement is valid only for the JADS EW test. The CROSSBOW sponsored Threat Simulator Linking Activity (TSLA) Network Specification indicates that the JADS latency budget is not as restrictive as other types of testing will require. Each type of HLA federation will have to make their own assessment of critical performance factors and determine key metrics for acceptable federation performance.

3. RTI Test Philosophy

The RTI test philosophy simply stated is to operate the RTI in a series of hardware/software configurations to determine RTI performance as variables which may impact performance are changed. Each RTI test environment is designed to build upon previous testing. Together the environments form a series of filter screens that increase user confidence in RTI performance while isolating increasingly complex federate interactions for examination.

The first environment is a simple computer-to-computer architecture intended to mimic tests done by RTI developers. The environments increase in complexity until the entire federation network architecture (except for T-1 lines) is in place. These represent development type tests that are designed to determine RTI baseline performance. The final test is an operational type test that will use the federates, (or acceptable surrogates), message structures, and data that we will be using in the actual federate execution. At this time we will also be characterizing the network bandwidth utilization and latency. Once we are convinced the network will meet our needs, we will bring the T-1 connections up and repeat a portion of the testing using the long haul communications network.

During the entire RTI test, we will be treating the RTI as a black box component that has been added into a known network architecture. We've chosen that approach to best imitate a future customer that has little or no insight into the RTI providers software development and testing process.

We have not identified all the software tools and test stubs that will be used during each phase of the testing. Our intent is to reuse DMSO test tools as well as test stubs of our own creation to allow comparison of results between like hardware/software configurations and validation of the developed test stubs.

4. RTI Test Objectives

The primary objective of the RTI testing is to ensure that JADS has an acceptable communications infrastructure for each test federation in order to recreate the OAR test environment. Acceptable means that all hardware and software components are behaving as required and that the total system latency is within budget over the expected range of message rates and sizes used to recreate the OAR test event interactions. RTI testing is necessary for the JADS EW test program because the federations are producing EW performance data that will be carefully measured and compared between the test phases. Any variability in test results introduced by RTI, the other communications infrastructure components, the federates, or the Federation Object Model must be identified and measured prior to actual EW test events.

In order to feed RTI test results back into the federation design we must understand the behavior of the RTI around our expected performance envelope. The results of the RTI testing will be used to guide any simulation object model changes that may be required to meet the total end-to-end interaction latency requirement. It may be possible to make minor modifications to the message structures, update rates, interactions, or other aspects of the infrastructure to optimize federation communication. Such tuning should be planned for in the development of high performance federations.

5. RTI Test Approach

As stated earlier, the RTI will be operated in a series of controlled test environments. The first environment uses an SGI O2 5000 and an SGI O2 10000 running IRIX 6.3 connected via a dedicated Ethernet connection. The first test set will use DMSO test tools to establish baseline performance and functionality of the system. The second test set will use the test stubs and procedures that will be used for the rest of the RTI testing. These stubs are simple variations of the data playback federates. The set begins with fixed message update rate, a fixed tick rate, and variable message size. The message size is then fixed and the message rate is allowed to vary. Then both the message rate and size are fixed and the message is passed first as an attribute update and then as an interaction. Finally, the tick rate is varied. Throughout all these tests, the total RTI induced latency (time from entrance into the RTI until time of exit) is being measured. While this paper concentrates on describing a methodology for JADS RTI testing, the reader should be aware of the fact that associated communications link throughput, latency, and hardware/software configurations, as examples, are also being tested. All sources of possible latency are being measured through a disciplined process of adjusting one variable at a time and collecting elapsed time data for the same transaction in differing reference test conditions..

The second environment uses the same computers connected as shown in Figure 5.1 to form two network segments. The test set will follow the same process as the previous test set using the JADS test stubs. This hardware will be implemented, baseline performance will be measured, and RTI functionality will be verified prior to the start of performance testing. The test progression will be the same as the first environment. Message rate, size, attribute/interaction, and tick are each examined around the values specified in the JADS EW test inputs in the RTI Performance Workbook.

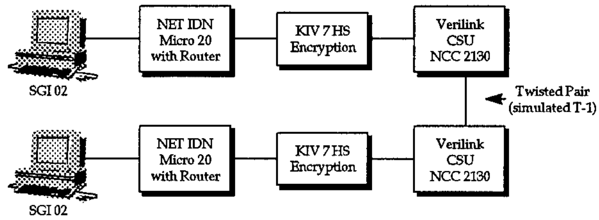

Figure 5.1 Two Segment Network Architecture

The third environment uses three computers on three network segments to match the network topology we will be using in our test. The topology is depicted below in Figure 5.2. The segment to segment connections use the components shown in Figure 5.1. Again RTI functionality is established prior to performance testing. This time, another variable is examined. After the attribute/interaction test, fixed rate and size messages are passed using first reliable transmission, then best effort to determine the impact of transmission type on system latency.

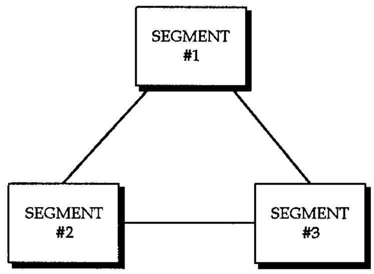

Figure 5.2 Three Segment Topology

Finally, three additional computers are added to one of the segments to represent the distribution of the multiple federates across the network. Network performance and RTI functionality are again measured. This time no additional performance testing is accomplished. This test set concludes the developmental type testing.

Operational type testing is accomplished by replacing the test stubs with either the actual federate or a surrogate for the federate. The concept is to allow all the federates to interact according to how they will interact during the test. The testing will begin with two federates interacting and build to all six interacting using actual data (where practical) in the real scenario. Finally, the network will be stress tested by adding objects, most likely missiles, into the scenario until system performance becomes unacceptable due to failure or excessive latency. It should be noted that for the purposes of the JADS EW test, the objects don't have to behave correctly, they just need to exist and pass updates to the subscribing federates.

After the successful completion of the development and operational testing, the testbed will be dismantled, shipped and reassembled as the wide area network to be used during the actual test. Subsets of the development and operational testing will be re-accomplished to verify the operation of the network and to characterize its performance. The final criteria to be met will be a graduation exercise by the network and JADS EW federates that will use actual sample test data and will cover all the observed interactions from the Open Air Range phase of the JADS EW test.

6.0 Conclusion

High performance federations must understand the communications infrastructure upon which they are built. An integral part of the infrastructure is the RTI. RTI testing for a federation must be accomplished in concert with network testing and should be a systematic characterization designed to identify the inherent performance of the network. That characterization can then be used to tune the federation object model so that the performance desired can be achieved. JADS EW is developing a test plan, procedures, and test stubs to accomplish communications infrastructure characterization. We will execute the characterization using RTI 1.3 and use the results to tune the FOM. Characterization will also be used in the VV&A of the federation prior to execution. Results and lessons learned will be provided to DMSO and the HLA user community.

REQUEST FOR DATA SYSTEMS SOFTWARE SUPPORT	DTIC-R CONTROL NO. A.	DTIC-Z TASK NO. B.

PART I - ORIGINATOR'S SUBMISSION

1. ORIGINATOR'S NAME	2. OFFICE SYMBOL	3. TELEPHONE	4.DATE OF REQUEST
Bonnie Klein	DTIC-OCA	767-8037	28 Jan 99

5. TITLE OF REQUEST Air Force Studies and Analyses (AFSAA) Electronic Library

6. DESCRIPTION OF REQUEST (STATE TYPE OF PRODUCT OR SERVICE, CONTINUE ON PLAIN BOND, IF NECESSARY)

Software support is requested to establish a special collection for AFSAA on DTIC's SIPRNET node which includes the following tasks:

(1) Create a collection of technical reports provided by AFSAA and incorporated via EDMS. This collection will be called the "AFSAA Electronic Library" and will include unclassified and classified citation information with links to the full-text documents.

(2) Establish and implement procedures for transferring the collection to the SIPRNET server and updating it on a regular basis.

(3) Copy all AFSAA recrods currently in TEAMS for the collection and link the inactive teams records to completed AFSAA Technical Reports.

(4) Restrict access by User ID/Password and later by fields and groups validation. Per DTIC-BCS, create a field in the subscription module for AFSAA; create a table for passwords; establish a product code for DURS.

7. PROJECT NUMBER (ATTACH COPY)	8. SCC CODE	9. DESIRED DELIVERY DATE FEB 99

10. JUSTIFICATION (STATE THE CURRENT SITUATION AND THE ANTICIPATED SAVINGS/BENEFITS)

This support is needed to fulfill an agreement between AFSAA and DTIC senior management (see attached draft MOA).

11. PSE SIGNATURE	12. DATE

PART II - DTIC-R REVIEW

1. RECOMMENDATION	2. REMARKS	3. DATE FORWARDED TO DTIC-Z
☐ ACCEPT ☐ REJECT ☐ DEFER UNTIL ________		4. ANALYST'S INITIALS

DTIC FORM 372, 19 JAN 99 (EG)

PART III - DTIC-Z ANALYSIS

1. ESTIMATED WORK HOURS

a. INITIAL ANALYSIS	b. DESIGN	c. CODING	d. TESTING	e. DOCUMENTATION	f. SYSTEM TESTING	g. OTHER	h. TOTAL HOURS

2. IMPACT ON OTHER WORKLOADS

3. RECOMMENDATION	4. ESTIMATED START DATE	5. ESTIMATED COMPLETION DATE

6. REMARKS

7. SIGNATURE	8. DATE

PART IV - ADMINISTRATOR'S DECISION

1.
- ☐ APPROVE
- ☐ DISAPPROVE
- ☐ DEFER UNTIL ____________

2. REMARKS

3. SIGNATURE	4. DATE

PART V - DTIC-Z CERTIFICATION OF COMPLETION

1. PERFORMANCE DATA

a. COMPLETION DATE	b. WORK HOURS	c. ADP PROGRAM RELEASE DATE
SCHEDULED	SCHEDULED	SCHEDULED
ACTUAL	ACTUAL	ACTUAL

2. REMARKS

3. ORIGINATOR'S ACCEPTANCE	DATE
5. SIGNATURE (DTIC-Z)	DATE

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D. Currently Applicable Classification Level: Unclassified

E. Distribution Statement A: Approved for Public Release

F. The foregoing information was compiled and provided by:
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